Children's Conceptual Structures of Science Categories and the Design of Web Directories

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Eleven middle school children constructed hierarchical maps for two science categories selected from two Web directories, Yahooligans! and KidsClick! For each category, children constructed a pair of maps: one without links and one with links. Forty-four maps were analyzed to identify similarities and differences. The structures of the maps were compared to the structures employed by the directories. Children were able to construct hierarchical maps and articulate the relationships among the concepts. At the global level (whole map), children's maps were not alike and did not match the structures of the Web directories. At the local levels (superordinate and subordinate), however, children shared similarities in the conceptual configurations, especially for the concrete concepts. For these concepts, substantial overlap was found between the children's structures and those employed in the directories. For the abstract concepts the configurations were diverse and did not match those in the directories. The findings of this study have implications for design of systems that are more supportive of children's conceptual structures.

Introduction

Web directories are used by increasing numbers of people to find information on the Web. Typically, these directories are designed on the basis of a hierarchical structure of subjects that are grouped into categories. Successful traversal within this structure requires that a user have adequate domain knowledge of the categories, knowledge of the relationships among the concepts associated with these categories, and the ability to place a topic within the appropriate categories.

Locating information by using Web directories is based on a browsing paradigm. Browsing is "an exploratory, information seeking strategy that depends upon serendipity. . . . [It is] especially appropriate for ill-defined problems and for exploring new task domains" (Marchionini & Schneiderman, 1988, p. 71). Browsing is valuable when a user is unable to articulate his/her information need. Belkin, Brookes, and Oddy (1982) maintain that a user's anomalous state of knowledge (ASK) can be a barrier to successful searching in query-based information retrieval (IR) systems.

Today's IRs, however, have facilitated finding information by offering both searching and browsing interface modes. Although searching may be preferred among Web users (Bilal, 2000; Wang, Hawk, & Tenopir, 2000; Watson, 1998), many users, and especially children, browse by following links more than they search by keyword (Bilal, 1998, 2000, 2001, 2002a; Large & Beheshti, 2000; Large, Beheshti, & Moukdad, 1999; Watson, 1998; Schacter, Chung, & Dorr, 1998). Indeed, browsing is often used as an alternative to the complex keyword-based search strategy (Marchionini, 1995) because it relies on users' recognition rather than recall knowledge. An IR system such as the Web may be difficult to use because it requires understanding of mechanical and conceptual aspects of searching as well as a high cognitive load.

Studies of children and adults have found differences between these two groups in terms of information seeking on the Web (Bilal & Kirby, 2002), information needs (Walter, 1994), pictorial representation of information (Pejtersen, 1992), concept learning (Bjorklund, 2000; Piaget & Inhelder, 1969; Siegler, 1998), and categorization of knowledge (Rosch, 1978). Thus, an IR system that is designed specifically for children should be congruent with these users' information needs, information seeking behavior, cognitive processes, knowledge structures, and expectations.

Despite the growing number of studies on children's interaction with the Web, no research has investigated whether the hierarchical design of Web directories matches children's conceptual representation of the same subject categories. The purpose of this study is to gain understanding of some aspects of middle school children's conceptual structures of subject hierarchies that are represented in two popular Web directories that are specifically designed for children, Yahooligans! and KidsClick! The findings of this study have

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implications for system design that is more supportive of children's traversal of Web directories.

Related Literature

Two main bodies of literature are relevant to this study: Children's Web browsing and children's categorization of knowledge.

Children's Web Browsing

"Browsing explores both the organization or structure of the information space and its contents" (Chen, Houston, Sewell, & Schatz, 1998, p. 583). Children and adults may "find it easier to recognize information presented to them rather than recall from memory" (Borgman, Hirsh, Walter, & Gallagher, 1995, p. 665). Studies of children's use of the Web reveal that children browse more than they search by keyword. In a study of 32 students in grades five and six, Schacter, Chung, and Dorr (1998) found that the students overwhelmingly browsed rather than searched by keyword and that browsing was more prevalent on an open-ended task than on a closed task. Large, Beheshti, and Moukdad (1999) in their study of 53 middle school students uncovered similar results. In a follow-up study, Large and Beheshti (2000) interviewed the same students to gather perceptions about their Web experience; they concluded that difficulty in searching by keyword resulted in frustration and that browsing was an alternative mechanism the children used to find information.

In contrast to the studies described earlier, in which children used Web engines designed for adults (Infoseek, Alta Vista), Bilal examined the information seeking behavior of 22 seventh-grade middle school students in using Yahooligans!, a Web directory designed for children ages 7–12. Bilal conducted three studies using three different tasks: fact based, research based, and fully self-generated (Bilal, 2000, 2001, 2002a). Findings showed that children's browse moves varied by task. They browsed most on the fully self-generated task, followed by the fact-based task and the research-oriented task. The variation in browse moves was caused by children's topic modification as they sought information for the fully self-generated task. Thirty-three percent of the children browsed under broad topics in order to find specific aspects of interest, and 26% modified topics during the process when they either lost interest in their topic or chose to explore another one. Children did experience problems with keyword searching, as most of the search queries they submitted resulted in zero retrieval on the fact-based task. Children's browsing behavior was influenced by the tasks they performed (Bilal, 2002b). Overall, children browsed less on the research-oriented (open-ended) task than on the fact-based (closed) task.

The browsing behavior observed in the studies cited focused on clicking and exploring hyperlinks rather than traversing the hierarchical structure of subject categories of the Web engines and directories used.

Children's Categorization of Knowledge

Borgman, Chignell, and Valdez (1989) assessed the ability of elementary school children (grades three to six) to sort terms into categories in the domain of science (*Animal* terms in one experiment and *Plant* terms in another experiment) that were paralleled in the IR interface of Project Seed. The latter had links to an encyclopedia of plant information and a database of science books on *Plant* topics, in addition to other curricular materials. The *Animal* and *Plant* terms were selected from glossaries of the grade science textbooks used in the children's magnet school. Findings indicate that children understood the *Animal* terms sufficiently well to categorize them but had difficulty with less familiar terms (i.e., *Plant*).

Building on the results of Project Seed, Borgman, Hirsh, Walter, and Gallagher (1995) designed the Science Library Catalog (SLC), a browsing system with a hierarchical structure that is based on the Dewey Decimal Classification. A group of 32 to 34 children, aged 9 through 12, participated in each of the four experiments that were conducted over a 3-year period. The authors found that children were able to search all four versions of the SLC effectively and quickly. However, when powerful navigation features (lateral browsing through the database) were added to the database in Version 3, children appeared to be lost. Similarly, when the database size increased in terms of depth of the hierarchies (from four to six) in Version 4, children had most difficulty navigating the system. Some topics with concrete subjects (e.g., birds) were easy for the children to find information on, whereas topics with abstract subjects (e.g., firefighting) were consistently difficult. The SLC was most effective in its simpler form with a basic hierarchical structure and a database structured in a four- rather than a six-level hierarchy. This study has implications for the design of hierarchical structures in information systems for children. Clearly, the deeper the hierarchies, the more likely children are to become lost. Similarly, the larger the database, the more difficulty children may have in locating information. Further, children are more successful in categorizing topics for concrete concepts than for abstract ones. Designing an effective hierarchical structure for a browsing system requires adequate understanding of children's cognitive processes and information seeking behavior. Cooper (2002) investigated primary- and intermediate-level children's classification behavior by asking them to classify terms representative of library books and to label them by categories. The results of this study were reported for children in grade one only. Children began with ideas about the books that a library should contain. Then they grouped those books into shelf categories and labeled these categories. The purpose was to examine the organization of the library through the eyes of the children. Children generated terms and labeled them by category. Using a hierarchical term-clustering technique and multidimensional scaling analysis, the author found that the largest cluster the children formed contained the category *Animals*, which the children labeled as such. Another cluster contained the terms of what could be considered easy, or picture book, fiction, which the children labeled as *Books*, *Cartoons*, or *Story*. As to where items should be placed on a library shelf, most of the terms on the far left side and the far right side of the clustering chart the researcher generated were real things (concrete). The terms clustered in the middle of the chart were things that were less real (abstract). Although Cooper did not examine children's organization and representation of categories against an existing IR system, the findings of her study indicate that an IR system that is designed for children should be supportive of their knowledge structures as well as cognitive developmental ability and processes (e.g., recognition of concrete vs. abstract concepts).

The studies reviewed clearly indicate that children are able to sort, group, and categorize terms, as well as provide labels to categories that are based on both perceptions and domain knowledge. Children are able to use hierarchies to locate information. However, they may experience difficulty in conceptualizing abstract concepts and traversing deep multilevel hierarchical structures in large databases.

Theoretical Framework

"What is a conceptual system and how is it organized? Do all people use the same conceptual system? If so, what is the system? If not, exactly what is there that is common to the way all human beings think?" (Lakoff, 1987, p. xi). What part of this conceptual system can be observed? Many researchers have examined human conceptual structures to describe the ways certain concepts are mentally interconnected in a specific domain of knowledge. One of the techniques that have been widely used to observe knowledge structure is concept mapping, which "visually describes the relationship between ideas in a knowledge domain" (Jonassen & Grabowski, 1993, p. 433).

Children are capable of drawing concept maps and grouping items on the basis of conceptual categories. Bjorklund (2000) notes that even 2- and 3-year old children have some understanding of terms for broad, subordinate categories (e.g., animals, food) and that they are cognizant of basic level categories before their second birthday. Lakoff (1987) notes that children are able to categorize at the basic level and that they acquire the general logic of classes or taxonomic categorization later.

Children's representation and classification of objects vary over the course of childhood. The earliest phase in classification is the idiosyncratic (also called *random classification*), which typifies most 2- and some 3-year-old children. At this phase, children group items in pairs and may not provide a rationale for their groupings (Piaget & Inhelder, 1969). The group items of 3- and 4-year-old children are based on perceptual characteristics (e.g., color, dimensions, scheme). Later, children between the ages of 5 and 6 classify items on the basis of complementary relations (also known as *functional*). After the age of 7, children can classify objects conceptually; that is, they group items on the basis of conceptual relations (e.g., similarity, categories) (Bjorklund, 2000).

One effective technique that has been employed for examining children's conceptual classification is concept mapping. Concept mapping has become increasingly useful as a research tool for brainstorming and as an instructional technique for facilitating cognitive learning since the publication of *Learning How to Learn* (Novak & Gowin, 1984). Novak's work is based on Ausubel's assimilation theory of cognitive learning (Ausubel, 1963, 1968; Ausubel, Novak, & Hanesian, 1978). Ausubel (1963, 1968) ascertains that a learner's previous knowledge is central to subsequent meaningful learning. Meaningful learning, as opposed to rote memorization, occurs when a person consciously and explicitly assimilates new information in the current knowledge structure. A key factor for potential success in meaningful learning is the framework of relevant concepts or propositions a person possesses. Novak (1998) and Novak and Gowin (1984) determined that one way to organize concepts into existing knowledge structures meaningfully is through the use of concept maps. Concept mapping was originally developed to diagram science concepts; however, this technique has been widely employed in designing complex structures (hypermedia, large Web sites), learning by explicitly integrating new and old knowledge, and assessing understanding or diagnosing misunderstanding (Plotnick, 1997). Glaser (1996) notes that well-organized structures facilitate problem solving and other cognitive activities and that differences in cognitive structures may be caused by the way in which knowledge is organized in a person's memory (based on previous knowledge and experience).

One of the principles that guided this study is use of the concept mapping technique. This technique has been effective with middle school students studying science (Novak, Gowan, & Johansen, 1983; Ruiz-Primo, Schultz, & Shavelson, 2001; Stice & Alvarez, 1987). Our assumption was that middle school children possess a certain level of conceptual structure about specific categories in the science domain they have been introduced to in the classroom. In addition, they are able to construct concept maps that reflect their mental representation of these concepts.

Another principle that guided this study is the user-centered design paradigm that measures the utility of any information retrieval system based on its "representation schemes for data sets that are consistent with human perception of those data sets" (Newby, 2001, p. 1030). On the basis of this paradigm, one can argue that the success of a hierarchically structured Web directory mainly depends on having an interface tailored to children's needs and cognitive developmental ability. Our assumption was that the more overlap we found between these structures, the more successful children would be in traversing these directories.

Research Questions

This study was designed to examine the concept maps children construct for science concepts and how well these maps match those employed in Yahooligans! and KidsClick! We addressed the following questions:

1. What conceptual structure do children generate for the science concepts selected from Yahooligans! and KidsClick!?
2. What similarities exist among children's conceptual structures?
3. What is the level of consistency between the concept maps children construct for science concepts selected from Yahooligans! and KidsClick!?
4. To what degree do the conceptual structures for science concepts in Yahooligans! and KidsClick! match children's conceptual structures of these concepts?

Research Design

This study employed a quasi-experimental design method that used the Construct-A-Map From Scratch Technique (Ruiz-Primo, Schultz, & Shevelson, 2001). In this technique, the experimenter provides the concepts and participants construct a hierarchical or a nonhierarchical map by using these concepts. In this study, the participants (middle school children) were asked to perform two tasks: (1) sort and organize concepts from general to specific, such as a tree), an activity similar to "topic outlining" they learned in the classroom (Session 1); and (2) draw a map of the sorted concepts on paper (Session 2).

Participants

This study took place at a middle school (the name is not disclosed for confidentiality) located in Tennessee. A list of seventh-grade science students (90 in total) was obtained from the school librarian, and letters were sent to the parents of the students requesting their consent for their children's participation in the study. Twenty-nine approvals were returned, of which 14 were females and 15 males. These students were called to the library with the permission of their teacher. The researcher and the librarian described the purpose of the study to the students and asked their assent to participate in the study. Thirteen students agreed; of them 2 took part in pilot testing, leaving the remaining 11 students in the sample.

Selection of Concepts

Because domain knowledge is important for providing adequate representation of conceptual structures (Glaser, 1996), we ascertained from both the science teacher and the school librarian the adequacy of the children's level of knowledge of the domain of science, including the categories *Science and Nature* (Yahooligans!) and *Health and Family* (KidsClick!) from which the concepts were selected. We also learned from the children verbally that they had used a variety of Web search engines but not Yahooligans! or KidsClick!

We selected 2 of 17 subcategories from the main Yahooligans! category *Science and Nature*, which are *Animals* and *Space*. This selection resulted in a total of nine concepts (Figure 1). We also selected four of five subcategories from the main KidsClick! category *Health and Family*: *Medicine*, *Disabilities*, *Family Life*, and *Exercise*. *Parenting*, the fifth subcategory, was excluded because it is not designed for children. This selection resulted in a total of eight concepts (Figure 2).

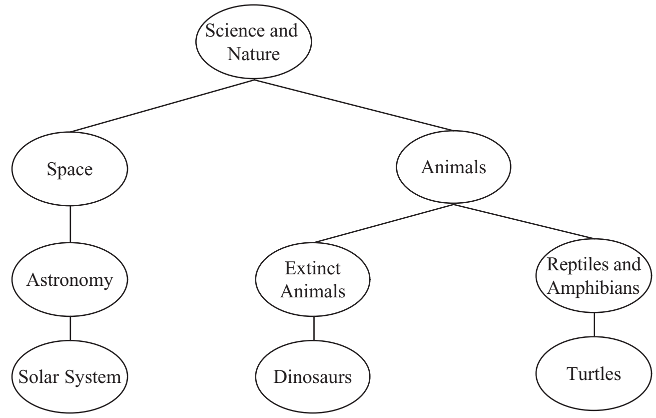

FIG. 1. Yahooligans! concepts for *Science and Nature.*

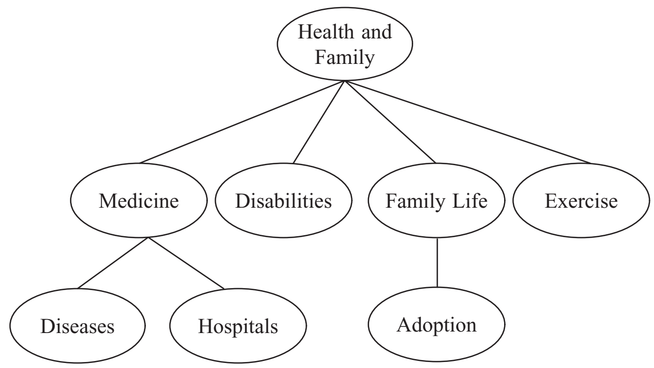

FIG. 2. KidsClick! concepts for *Health and Family*.

Yahooligans! and KidsClick! include different subject areas, employ different labeling of categories, and have different hierarchical structures. Yahooligans! structure is based on a proprietary organization scheme, whereas KidsClick! structure is based on the Dewey Decimal Classification. Yahooligans! tends to be more tied to school curriculum than KidsClick! For example, it places the concept *Extinct Animals* between *Animals* and *Dinosaurs*. KidsClick!, on the other hand, does not have *Extinct Animals* in its structure. The concepts related to the category *Health and Family* are dispersed in Yahooligans!, whereas they are well structured in KidsClick!; therefore, we selected these two main categories from these two directories for comparison.

Procedures

The study was conducted in May 2001. The experiment was carried out in six sessions, three for *Yahooligans!* and three for *KidsClick!* Data were collected by a research team consisting of the researcher (first named author), two school librarians (one senior and one junior) who were hired as consultants, and one trained graduate assistant in information science. The researcher prepared a set of written guidelines for the research team to use during data collection and a set of instructions for the children to follow as they completed each task.

Each concept was typed on a 2- by 4-inch card and two sets of cards were made: Set I included nine concepts from the Yahooligans! category *Science and Nature* plus one unrelated concept (*Music*), totaling 10 concepts. Set II had eight concepts from the KidsClick! category *Health and Family* plus two unrelated concepts (*Space*, *The Environment*), totaling 10 concepts. We included the unrelated terms to assess children's level of cognizance of category boundary. Each participant produced two maps for each set of concepts (two from Yahooligans! and two from KidsClick!) generating a total of 44 maps.

Data collection occupied half a day and spanned six sessions, three for Yahooligans! and three for KidsClick!

Session I—Maps Without Links (Yahooligans! Session 1)

Each child was seated at a table in the school library and given Set I cards to sort. Each set was labeled with the letter *Y* (for *Yahooligans!*) and contained the child's identification number. The school librarian explained this task to the children through examples on a flip chart. Children were given an instruction sheet with examples of how to complete this task and were encouraged to ask questions as necessary. Children were to sort the cards into three categories, one for general subjects, one for specific subjects, and one for most specific subjects, using topic outlining they learned in the classroom. They were also to arrange the sorted cards in the form of a tree and leave them on the table. When the task was completed, children took a 15-minute break, during which the research team recorded the maps by hand copying the arrangements of the cards. The arranged cards remained the same on the tables for the children to use for the following sessions. The children took an average of 15 minutes to complete this task.

Session II—Maps With Links (Yahooligans! Session 2)

Children reviewed the arranged cards and were given paper and pencil to draw maps based on these cards. They were introduced to this task verbally and were shown examples of how to construct such maps. The concept of topic outlining and connecting of related topics were reviewed verbally and an instruction sheet containing examples of connected related topics was given to the children. When finished, children took a 15-minute break, during which the research team collected the drawn maps. The children took an average of 20 minutes to complete this task.

Session III—Interviews (Yahooligans! Session 3)

Using an interview instruction sheet, each member of the research team interviewed two or three children individually. In addition, each team member had a hierarchical map of the Yahooligans! concepts for *Science and Nature* to use as a reference (Figure 1). Each child was asked to identify the concept(s) he/she placed at each level of the hierarchy verbally and was asked to provide a rationale for the arrangement. Follow-up questions were asked about the concepts that children placed differently from those on the Yahooligans! map. The average time to complete each interview was 10 minutes. Each interview was audiotaped and transcribed.

Session IV—Maps Without Links (KidsClick! Session 1)

Session IV employed the same procedure as Yahooligans! Session 1 to configure the cards for the category *Health and Family* (Set II cards).

Session V—Maps With Links (KidsClick! Session 2)

Session V employed the same procedure used in Yahooligans! Session 2 to produce the maps with links for the category *Health and Family* (Set II cards).

Session VI—Interviews (KidsClick! Session 3)

The interviewing procedure was identical to that used for Yahooligans! Session 3. Each team member had a hierarchical map of the KidsClick! concepts for *Health and Family* to use as a reference (Figure 2). The average time to complete each interview was 12 minutes. Each interview was audiotaped and transcribed.

Results

The data gathered for this study were analyzed by using descriptive statistics to generate percentages and mean values. The children were able to construct hierarchical maps and draw the relationships among the concepts. The concepts that were given to the children from each directory included unrelated terms to observe children's level of knowledge of the boundary of the categories. The results show that although all children excluded the term *Music* from the category *Science and Nature*, 10 (82%) excluded *Space* and 5 (45%) excluded *The Environment* from their maps. Two (18%), however, excluded the related term *Exercise* from their maps.

We examined the similarities among the structures children constructed. We analyzed the hierarchical maps (MLs) on the basis of the "traversal path" of hierarchically organized concepts, that is, the logical path a user should follow to locate information in each of the directories for the selected concepts. The traversal paths in each Web directory were compared to those of the children, and percentages of matches were generated.

The results of this study are reported in relation to the research questions posed.

What Conceptual Structure Do Children Generate for the Science Concepts Selected From Yahooligans! and KidsClick!?

A map can be examined for its structure and content. The former measures the configurations, and the latter measures the relationships at both the global (whole map) and local (superordinate and subordinate) levels. Children constructed hierarchical maps for the categories *Science and Nature* and *Health and Family*. These maps are in the discussion that follows.

Children's Concept Maps

Children's hierarchical maps were examined in terms of depth and breadth of categorization. *Depth* is the number of levels from the top level to the lowest end of the tree. *Breadth* is the number of parallel subordinate categories that are derived from a superordinate category at each level of the hierarchy. For example, *Animals* (Figure 1) is a subordinate concept to *Science and Nature* but a superordinate concept to both *Extinct Animals* and *Reptiles and Amphibians*. Depth is a single number, whereas breadth is a range of numbers. In a hyperlinked structure such as the one employed in Web directories, depth relates to the length of a path a user must traverse in order to get to the target object. Breadth, however, pertains to alternative paths a user must decide to traverse at each point in the structure in order to get to the target object.

We calculated the mean number of concepts the children had in their maps in terms of depth and the range of numbers for breadth. The mean depth in children's maps was 3.91 compared to 4 in the Y map (Yahooligans!). Children's maps' breadth level ranged from 1 to 4 compared to 1 to 2 in the Y map (Table 1).

Children's maps for the KidsClick! concepts had a mean depth of 4.18 compared to 3 in the K map (KidsClick!). The breadth of the maps ranged from 1 to 3 compared to 1 to 4 in the K map.

What Similarities Exist Among Children's Conceptual Structures?

Children's maps were examined to identify similarities in conceptual structures at both the global and local levels. For the Yahooligans! concepts, at the global level, all children placed *Science and Nature* at the top level of the maps.

TABLE 1. Comparison of children's maps to the Yahooligans! and KidsClick! maps.

Characteristics	Children's maps for Yahooligans! (*n* = 11)	Yahooligans!	Children's maps for KidsClick! (*n* = 11)	KidsClick!
Mean depth	3.91	4	4.18	3
Breadth range	1–4	1–2	1–3	1–4

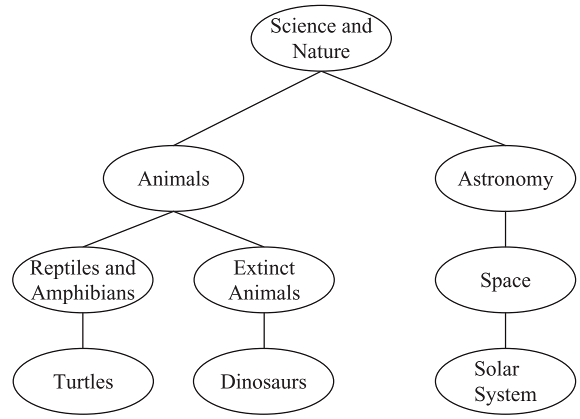

FIG. 3. Similarities in the children's structure of the *Space* concepts.

Among these, one child had *Astronomy* in parallel with *Science and Nature* and another one had *Animals* in parallel with *Science and Nature*.

At the local level, however, we found more shared structures in the maps. For the five concepts related to *Animals*, the structure was shared by 64% of the participants. This structure looked the same as that displayed in Figure 1. Six children (55%) had the same structure for *Space* (*Astronomy–Space–Solar System*) (Figure 3). Two children (18%) placed both *Solar System* and *Astronomy* in parallel under *Space*. The rest of the children had diverse structures for these concepts with no similarities.

With regard to the KidsClick! concepts, at the global level, the children's maps varied. Six children (55%) placed *Health and Family* at the top level of the maps. Among these, one child had *Family Life* in parallel with *Health and Family*. Four children (36%) placed *The Environment*, an unrelated term, at the top level, and one child placed *Family Life* at the top level.

At the local level, children had five different shared configurations for the concepts related to *Health and Family* (Table 2).

TABLE 2. Similarities across children's local configurations.

Configuration	Concepts	No. of children (*n* = 11)	Percentage
1	Hospitals<superordinate> Diseases<superordinate> Medicine	3	27
2	Hospitals<superordinate> Medicine<superordinate> Diseases	3	27
3	Hospitals<superordinate> Disabilities	5	45
4	Family Life<superordinate> Adoption	8	73
5	Family Life<superordinate> Disabilities	2	18

Overall, placing concepts in super- and subordinate relationships was a challenge for the children, and reasons for a particular structure were not strongly justified all of the time: "Because it's the broadest, one of the broadest terms" and "Because it is the broadest topic of them all." The child who placed *The Environment* under *Family Life*, for example, said, "Because I thought the environment was related to family life."

We observed a difference in the way children constructed categories for concrete and abstract concepts. Within the *Science and Nature* category, for example, seven children (64%) shared the structure for the five concrete concepts related to *Animals*, and 55% shared the structure for the three concepts related to *Space*. Within the *Health and Family* category, we found that the most shared structure was for the two concepts *Family life* and *Adoption* (73%). Abstract concepts were shared the least among the children. These were *Hospitals* and *Disabilities* (by 45%); *Hospitals*, *Medicine*, and *Disease* (by 27%); *Hospitals*, *Diseases*, and *Medicine* (by 27%); and *Family Life* and *Disabilities* (by 18%).

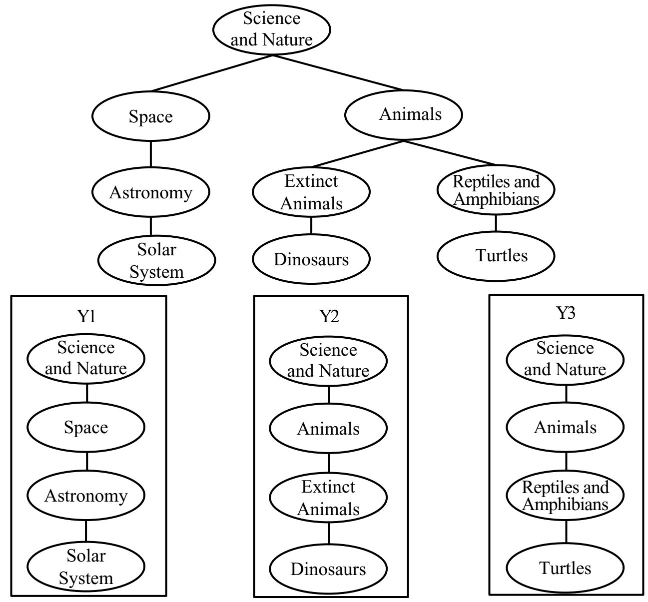

FIG. 4. Yahooligans! map and partition.

What Is the Level of Consistency Between the Two Groups of Maps Children Constructed for the Science Concepts Selected From Yahooligans! and KidsClick!?

We examined the level of consistency between each pair of maps each child configured for concepts from each of the directories. We looked at the number of concepts that each child configured identically for each pair of maps. If the two maps were identical, then the consistency is 100%. Each pair contained one map without links (MWL) and one with links (ML). The former was constructed by sorting the concept cards and organizing them in the form of a tree on the table; and the latter was constructed by basing the drawing of the structure on the sorted concepts.

With regard to the concepts for *Science and Nature* (Yahooligans!), only 36% were consistent. As to the concepts related to *Health and Family* (KidsClick!), 90% had MLs that were consistent with the MWLs.

To What Degree Does the Conceptual Structure for Science Concepts in Yahooligans! and KidsClick! Match Children's Conceptual Structure of These Concepts?

The comparison of children's maps focused on the hierarchical relationships of the categories. Such relationships allow one to understand how each child represented the hierarchy of the categories. This comparison is challenged by the fact that children's maps were not alike and that none matched the global structure in either directory. However, at a local level, analysis of a part of the map, such as a selected branch, may reveal similarities or overlaps with the structure employed in each of the directories for the same branch. Therefore, we partitioned each child's map on the basis of

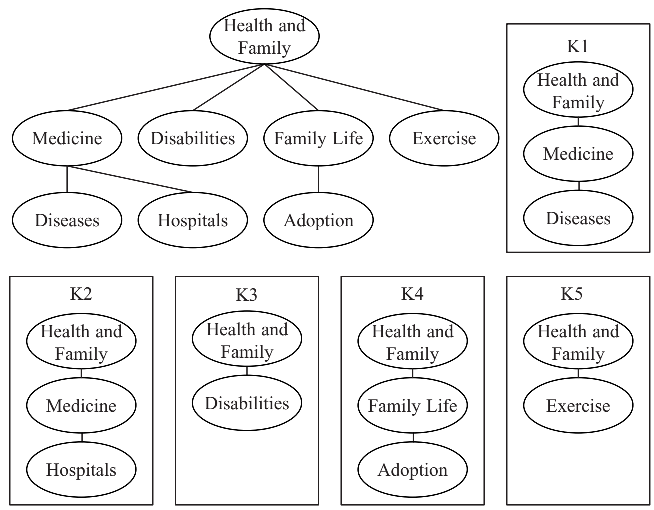

FIG. 5. KidsClick! map and partition.

"traversal path" of hierarchically organized concepts, that is, the path a child is likely to follow in each of the directories to find information on the target concept.

Accordingly, we partitioned the Yahooligans! map into three branches (Y1–Y3) (Figure 4) and the KidsClick! map into five branches (K1–K5) (Figure 5). We compared each child's hierarchical map (ML) to the corresponding partitioned map for Y and K.

Three children (27%) had maps that matched Y1, and seven (64%) that partially matched Y1 as they had *Space* and *Astronomy* in reverse order. Eight (73%) of the maps matched Y2 and nine (82%) matched Y3.

Children had diverse structures for the concept: *Space*, *Astronomy*, and *Solar System* (Y1). Those who placed *Astronomy* above *Space* did so because "astronomy was more remote than space. . . . Space is like more . . . uh astronomy is the study of space," and "because astronomy is

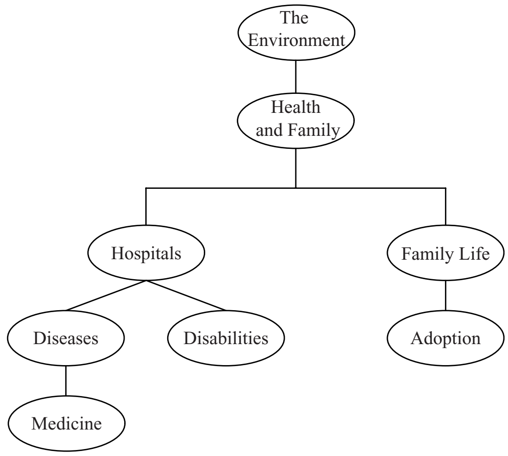

FIG. 6. Children's shared configuration of the *Medicine* concepts.

science . . . space is a form of science," and "because astronomy is the study of space," [and *Space*] is "the broadest of astronomy" and "I'm not sure . . . because it's more specific I guess." Those who placed *Solar System* under *Space* rather than under *Astronomy* said, "There are many solar systems in space," and "because it's under space . . . um . . . or above it," and "because the solar system is more specific than space."

Children's maps for *Health and Family* (KidsClick!) reveal that only one map matched K1, 91% matched K2, no map matched K3, 36% matched K4, and another 36% matched K5. Children's conceptualization of the relationships among the concepts was often "perceptual," "experiential," and "situational." The two children who placed *Disabilities* under *Family Life*, for example, said: "In a family you might have disability," and [it] "would be a disability of the family and adaptations of the family." The children who placed *Disabilities* under *Hospitals* explained that "hospitals treat disabilities," and disabilities "happen in a hospital," and "usually people with diseases and disabilities are in hospitals." Similarly, the children who placed *Medicine* under *Diseases* and *Diseases* under *Hospitals* (Figure 6) noted: "You came to the hospital when you have a disease," and "medicine treats disease," and "you get medicine at hospitals." The children who placed *Adoption* under *Family Life* said: "Your family may adopt a child," and "usually family adopt kids," and "adoption is a part of family life" and "because it fit under family life best," and "because it is the most specific of them all." Although most children (73%) placed *Adoption* under *Family Life* similarly to the discipline-oriented structure employed in KidsClick!, 45% perceived *Hospitals* as a place for treating *Disabilities* and (27%) perceived *Medicine* as a "treatment" for *Diseases* rather than a discipline (Table 2).

Discussion

This study examined the kind of conceptual structure a group of middle school children constructed for science concepts selected from two Web directories that are specifically designed for their age levels, Yahooligans! and KidsClick! It compared children's structuring of these concepts to those employed in each of these directories.

This study was conducted in one middle school with 11 children who were selected from science classes. The children's level of knowledge of the categories selected from Yahooligans! and KidsClick! was assessed informally through the school librarian's and science teacher's point of view.

Because of federal regulations that require both parental consent and children's assent for their participation in research, securing a representative sample was not possible. Therefore, the results of this study may not be generalized to the whole population of middle school students.

Constructing concept maps by using the Construct-A-Map-From-Scratch technique (Ruiz-Primo, Schultz, & Shavelson, 2001) was simple for the children. It was also effective in providing information about the level of children's knowledge of the conceptual relationships among selected concepts in the science domain. The hierarchical maps children constructed on paper allowed researchers to understand the children's conceptual structure and mental representation of the relationships among the concepts presented at both the global and local levels. The maps without links (MWLs) were effective in that they served as a brainstorming activity for constructing the maps with links (MLs).

Children's conceptual structures for both *Health and Family* (KidsClick!) and *Science and Nature* (Yahooligans!) did not match the global structures employed in either directory. When these structures were partitioned into branches, however, we were able to find the branches of the structures that children constructed and those they did not. Children had more diverse structures for the concepts related to *Health and Family* than for those related to *Science and Nature*. Apparently, children were more knowledgeable about *Animals* than about *Space*, *Astronomy*, and *Solar System.*

The nature of the concepts within each category (concrete vs. abstract) may have contributed to the diversity in the structures observed. Children shared more similarities in their structures of concrete categories than in those of abstract categories. Similarly, children's structures had more overlap with those of the directories for concrete than for abstract concepts. The level of abstraction of certain concepts may have influenced the ways children organized these concepts in terms of depth and breadth. For example, children had more than four levels of depth on their maps, as opposed to three on that in KidsClick! The breadth of concepts in the children's maps ranged from 1 to 3, as opposed to 1 to 4 in KidsClick!

The finding that all children excluded the term *Music* from the category *Science and Nature* but did not exclude *The Environment* and *Space* from the category *Health and Family* indicates that the boundary for the latter category was unclear in the child's mind. From the cognitive point of view, not all categories have clear boundaries (Lakoff, 1987). This characteristic raises the question of whether *The*

Environment can be a part of *Health and Family* and whether its being a part depends on the definitions given to the category.

Because children were aged 11–13, we expected that the groupings of their concepts would be based on conceptual relationships. Surprisingly, we found that most of the structures were based on perceptual, experiential, and situational relationships. Use of such relationships may have been based on trial and error, because children did not have sufficient knowledge to manipulate some of the concepts. The children in this study were at the development age described by Piaget and Inhelder (1969) as the formal operations stage. At this age, children have the ability to use internalized abstract operations based on general principles to predict the effects of operations on objects. Thinking, problem solving, and analogical reasoning can take place in a purely abstract framework. In this study, when children were uncertain about a concept and its relationship to other concepts, they adopted the goodness-of-fit strategy based on intuition, as was evident in statements such as "it doesn't fit under . . . " and "it fits best here."

Implications

The results of this study reveals that the children's conceptual structures for many concepts in the science domain were "situational," "perceptional," and "experiential" rather than conceptual.

Children had difficulty constructing maps for the KidsClick! category *Health and Family*. KidsClick! organizes concepts on the basis of the Dewey Decimal Classification, which is discipline oriented. Although Yahooligans! employs a proprietary classification scheme, its structure of hierarchies is also discipline oriented.

On the basis of the rationale that children elicited for organizing abstract concepts, we believe that they were able to "internalize" these concepts but were unable to classify them from a discipline point of view, especially because they did not possess sufficient knowledge to manipulate these concepts. When children's cognitive structures do not match the structures employed in an IR system, such as Yahooligans! and KidsClick!, children are most likely to become disoriented or lost in these directories. Understanding a user's knowledge structure can optimize the design and use of an IR system (Wang, 1999). Directories that are designed for children should model cognitive structures into the system and incorporate different situations to accommodate children's traversal behavior and information needs.

Browsing is challenging to both the information seeker and the system designer. Marchionini (1995) notes that the first aspect of browsing is identification of an entry point. Here, the information seeker must relate personal knowledge about the topic to "what the system represents and how its representations are organized" (p. 101). Yahooligans! does not have an entry point for *Astronomy* from its main page, for example, and it lists *Space* under *Science and Nature*. Once *Space* is visited, the concept changes to *Astronomy and Space* (as of April 20, 2004). This concept can be difficult for children. A child who wants to find information on *Astronomy* will have to recognize that *Astronomy* is a subordinate category of *Space*; otherwise, the child is unlikely to find information on this concept efficiently. Not only is the labeling of the concept inconsistent; the order in which it is represented (*Astronomy* before *Space*) is misleading, as well.

Children's browsing on the Web, especially their traversal behavior of hierarchies, can be much improved. The organization of concepts in a Web directory is important because successful traversal to a specific concept depends on a match between a child's conceptual structure of the hierarchy and the structure employed in the directory.

The findings of this study have implications for system design, as well future research.

System Design

Humans classify objects differently in a social context. Some individuals use categorical classification; others may use situational classification. Ingwersen (1992) argues that situational classifications provide contexts, whereas categorical classifications often have the form of abstract relations. He also notes that an IR system designer who has some knowledge of the user population should tailor the classification of topics and concepts accordingly.

The design of an optimal visual interface that displays the hierarchical structure of concepts in navigational maps of some form would certainly facilitate children's browsing. The addition of a thesaurus to show concepts and their relationships to other concepts could assist children in selecting appropriate concepts by using recognition rather than recall knowledge. Adding qualifiers for terms, such as *Medicine* (*as a science*) and *Medicine* (*as a treatment*) may assist children in selecting appropriate concepts and traversing their hierarchical structures.

System designers should investigate various information retrieval techniques and mechanisms that support children's browsing of the hierarchies in these two Web directories. One of these is use of a neural network learning algorithm and Kohonen's self-organizing map algorithm (Lin, Marchionini, & Soergel, 1993). Kohonen's algorithm category map and self-organizing map (SOM) have recently been applied to support user browsing of the taxonomies of Yahoo (Chen, Houston, Sewell, & Schatz, 1998). More recently, Chi, Pirolli, Chen, and Pitkow (2001) introduced an algorithm to simulate Web traversal behavior of users who are following existing imperfect browsing cues. Concept mapping has also been employed to support Web browsing and searching (Carnot, Dunn, Canas, Gram, & Muldoon, 2001; Carvalho, Hewett, & Canas, 2001).

Future Research

In this study the children were asked to configure hierarchical maps for concepts in the science domain. Further research should consider allowing children to draw maps by using preferred structures. Research has shown that human beings organize concepts in their memory by using other structures (e.g., spider maps) (Jonassen & Grabowski, 1993). In a study by Wang (1999), for example, the participants were asked to arrange concepts in ways that made sense to them. The results showed that expert researchers tended to map their concepts in nonhierarchical configurations (e.g., weblike with centered concepts). Given the same terms, nonexpert researchers tended to construct hierarchical maps. Nonexperts were those who had learned these concepts but did not conduct research on the topics.

Our study did not examine children's conceptual style before data collection. Using a Conceptual Style Test could provide a richer and deeper understanding of the children's competency performance in conceptualization strategies. Such a test measures three conceptualization modes: rational–thematic, inferential–categorical, and analytic–descriptive (Kogan & Saarni, 1989).

Learning style may be a factor in the ways children build knowledge structures. Such a style has been used to assess the knowledge structures of graduate students (Wang, Bales, Rieger, & Zhang, 2004) but has not been applied with children. Researchers may want to investigate this area of study.

Conclusions

This study provided some understanding of the nature of children's conceptual structures for certain categories in the science domain. Children are able to construct hierarchical maps and articulate the relationships among concepts. Children do not share conceptual structures globally among themselves; however, they have common thinking for structures at the local level. These structures are more similar for concrete than for abstract categories. Further, for the concrete concepts, children's structures match comparatively well with the structures employed in Yahooligans! and KidsClick! Children's structures for abstract concepts do not match those employed in these directories. The difference between the structures is caused by the principles used to map the relationships among concepts. Children's approach is perceptual, situational, and experiential (concrete), whereas the approach used in these directories is discipline oriented (abstract).

This line of research is a fruitful area of study, especially because it contributes to our understanding of the way knowledge is organized in the child's mind. Children can be good partners in designing new technology, such as digital libraries (Druin, 2002), and Web interfaces (Bilal, 2003). As children's use of Web engines grows, system designers should involve them in the design of Web directories by applying multiple representations of conceptual structures that incorporate children's knowledge structures.

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